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METHODS FOR PREPARATION OF BUFFER SOLUTIONS

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MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

Gr 4 *October* 1965

Indian Standard

METHODS FOR PREPARATION OF BUFFER SOLUTIONS

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Indian Standard

METHODS FOR
PREPARATION OF BUFFER SOLUTIONS

0. FOREWORD

0.1 This Indian Standard was adopted by the Indian Standards Institution on 12 April 1965, after the draft finalized by the Chemical Standards Sectional Committee had been approved by the Chemical Division Council.

0.2 In this standard, a series of buffer solutions have been prescribed. It is expected that they will cover the common experimental conditions and be useful for control of *p*H measurement in industry. Different buffer solutions for the same *p*H range have been mentioned in order to offer a choice of a particular buffer for specific experiment.

0.3 The *p*H is given at different temperatures for different buffer solutions as data for a uniform temperature for these solutions were not available. It is intended to adopt a uniform temperature of 27°C for all of these solutions when the required data become available.

0.4 In preparing this standard, assistance has been obtained from the following publications:

BS 1647 : 1961 Specification for *p*H scale. British Standards Institution.

Bates (R G). Determination of *p*H, theory and practice. 1964. J. Wiley & Sons Inc., New York.

Food chemicals codex. 1963. Committee on Specifications, Food Chemicals Codex National Academy of Sciences, Washington.

1. SCOPE

1.1 This standard prescribes the methods for preparation of buffer solutions used in analytical and control laboratories in industry.

1.1.1 Primary and secondary standard buffer solutions for calibration of *p*H meters are also included in this standard.

2. TERMINOLOGY

2.0 For the purpose of this standard, the following definitions shall apply.

2.1 Buffer Value, $\beta \left(= \frac{dm}{dp\mathrm{H}} \right)$ — The moles of a strong acid or strong base when added to one litre of a solution to change its pH value by a unit.

2.2 Dilution Value ($\Delta p\mathrm{H}\frac{1}{2}$) — The change of pH units if a buffer solution is diluted with an equal volume of water.

2.3 Molality (m) (of a Solution) — The amount of solute in moles per 1 000 g of the solvent.

2.4 Molarity (M) (of a Solution) — The amount of solute in moles in one litre of the solution.

2.5 Temperature Coefficient $\left(\frac{dp\mathrm{H}}{dt} \right)$ — The change of pH units per degree Celsius (Centigrade) rise of temperature.

3. REAGENTS

3.1 The reagents of the purity specified against each in **3.1.1** to **3.1.19** shall be used in the preparation of the buffer solutions. Freshly boiled and cooled distilled water shall be used for the preparation of all buffer solutions.

3.1.1 *Acetic Acid* — (CH_3COOH; Molecular Weight 60·05) pure (conforming to IS : 695-1955*).

3.1.2 *Borax* — ($Na_2B_4O_7$, $10H_2O$; Molecular Weight 381·43) It shall contain not less than 99·5 percent and not more than 100·5 percent of $Na_2\,B_4O_7$, $10H_2O$ and shall conform to the limits of impurities given below:

	Percent by Weight, Max
i) Carbonate (as CO_3)	0·05
ii) Chloride (as Cl)	0·001
iii) Sulphate (as SO_4)	0·005
iv) Calcium (as Ca)	0·01

NOTE — Before use, the borax shall be gradually heated to 110°C and then its temperature raised to 400°C to dehydrate it completely.

---

*Specification for glacial acetic acid, pure, pharmaceutical and technical. (Since revised)

3.1.3 *Boric Acid* — (H_3BO_3; Molecular Weight 61·84) analytical reagent grade. Before use the material shall be spread in a dry vacuum desiccator at room temperature preferably overnight.

3.1.4 *Calcium Hydroxide Solution* — [$Ca(OH)_2$, Molecular Weight 74·09] Calcium hydroxide shall be prepared from calcium carbonate of low alkali grade after it has been washed thoroughly. Heat the carbonate slowly to about 1 000°C and ignite at that temperature for at least 45 minutes. After cooling, add the resulting calcium oxide slowly to water with stirring. Heat the suspension to boiling, cool and filter on a G3 sintered glass funnel. Dry the solid in an oven and crush to a uniform, finely granular state for use.

3.1.4.1 To prepare a saturated solution, shake vigorously an excess of calcium hydroxide, prepared as in 3.1.4, in a stoppered polyethylene bottle with water at room temperature. Allow the excess of solid to settle and remove the suspended material by filtration with suction on a G3 sintered glass funnel. It is advisable to determine the concentration of a saturated solution of a portion of calcium hydroxide prepared from each particular lot of calcium corbonate. If the concentration of the saturated solution at 25°C as determined alkalimetrically appears to exceed 0·020 6 M, the presence of soluble alkalis is indicated. Calcium hydroxide solution shall be free from soluble alkalis.

3.1.5 *Disodium Hydrogen Phosphate* — (Na_2HPO_4; Molecular Weight 141·97). It shall contain, after drying for 2 hours at 110±2°C, not less than 99·5 percent and not more than 100·5 percent of Na_2HPO_4. It shall conform to the limits of impurities given below:

	Percent by Weight, Max
i) Chloride (as Cl)	0·006
ii) Sulphate (as SO_4)	0·03
iii) Potassium (as K)	0·05
iv) Loss on drying at 120 ± 2°C	0·2

3.1.6 *Glycine* — ($H_2N.\ CH_2\ COOH$; Molecular Weight 75·05) It shall comply with the following requirements:

a) A solution of 2 g of glycine in 20 ml of water shall be clear.

b) It shall give no precipitate with barium nitrate solution.

c) It shall show only the slightest opalescence with silver nitrate solution.

d) The sulphated ash obtained from 5 g of glycine shall not exceed 2 mg.

e) The nitrogen content (by Kjeldahl method) shall be 18·67 ± 0·10 percent by weight.

3.1.7 *Hydrochloric Acid* — 0·1 N and 0·2 N.

3.1.8 *Phosphoric Acid* — (H_3PO_4, Molecular Weight 98·0) analytical reagent grade.

3.1.9 *Potassium Hydrogen Phthalate* — (HOOC. C_6H_4.COOK; Molecular Weight 204·22) It shall contain not less than 99·9 percent and not more than 100·1 percent of HOOC. C_6H_4. COOK and shall conform to the limits of impurities given below:

	Percent by Weight, Max
i) Chloride (as Cl)	0·001
ii) Sulphate (as SO_4)	0·01
iii) Sodium (as Na)	0·05
iv) Moisture	0·1

3.1.10 *Potassium Chloride* — (KCl; Molecular Weight 74·55) analytical reagent grade, recrystallized several times from water and dried at 120 to 150°C.

3.1.11 *Potassium Dihydrogen Phosphate* — (KH_2PO_4; Molecular Weight 136·09) The material, after drying at 110 ± 2°C, shall contain not less than 99·5 percent and not more than 100·5 percent of KH_2PO_4. It shall comply with the limits of impurities as given below:

	Percent by Weight, Max
i) Chloride (as Cl)	0·000 5
ii) Sulphate (as SO_4)	0·01
iii) Ammonia (as NH_3)	0·001
iv) Sodium (as Na)	0·05
v) Loss on drying at 110 ± 2°C	0·1

3.1.12 *Potassium Hydrogen Tartrate* — ($KHC_4H_4O_6$; Molecular Weight 188·18) The material, dried at 110 ± 2°C, shall contain not less than 99·8 percent of $KHC_4H_4O_6$. It shall comply with the limits of impurities as given below:

	Percent by Weight, Max
i) Chloride (as Cl)	0·001
ii) Sulphate (as SO_4)	0·01
iii) Iron (as Fe)	0·001
iv) Lead (as Pb)	0·001
v) Moisture	0·1

3.1.13 *Potassium Tetra-oxalate* — [KH_3 (C_2O_4)$_2$, $2H_2O$; Molecular Weight 254·19] The material shall contain not less than 99·9 percent and not more than 100·1 percent of $KH_3(C_2O_4)_2, 2H_2O$. It shall comply with the limits of impurities given below:

	Percent by Weight, Max
i) Chloride (as Cl)	0·002
ii) Sulphate (as SO_4)	0·01
iii) Calcium (as Ca)	0·005
iv) Sodium (as Na)	0·05

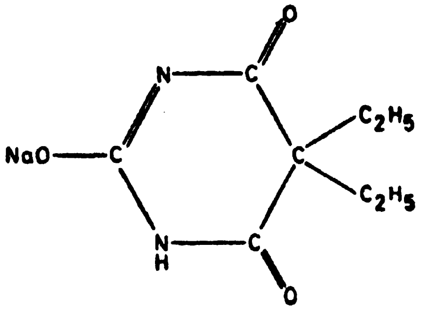
3.1.14 *Sodium Acetate* — ($CH_3COONa, 3H_2O$; Molecular Weight 136·08) analytical reagent grade.

3.1.15 *Sodium Bicarbonate* — ($NaHCO_3$; Molecular Weight 84·01) analytical reagent grade (conforming to IS : 2124-1962*).

3.1.16 *Sodium Chloride* — (NaCl; Molecular Weight 58·45) analytical reagent grade.

3.1.17 *Sodium Diethyl Barbiturate* (*Sodium Salt of Veronal*) — (Molecular Weight 206·18) It shall contain, after drying, not less than 98·5 percent of $C_8H_{11}O_3N_2Na$. It shall conform to the limits of impurities given below:

	Percent by Weight, Max
i) Loss on drying at 105°C	1·0
ii) Neutral or basic substances	0·2
iii) Lead (as Pb)	0·001



Sodium dicthyl barbiturate

3.1.18 *Sodium Hydroxide* — (NaOH; Molecular Weight 40·41) carbonate-free. 0·1 N and 0·2 N; standardized against 0·1 N and 0·2 N phthalic acid solution using phenolphthalein as indicator.

---

*Specification for sodium bicarbonate.

3.1.19 *Tris (Hydroxymethyl) AminoMethane* — $[(HOCH_2)_3 \equiv C(NH_2)]$

4. WORKING BUFFER SOLUTIONS FOR GENERAL PURPOSES

4.0 In case of tartrates, citrates, oxalates and phthalates working buffer solutions either fresh solutions shall be prepared or a drop or two of thymol solution shall be added as they are liable to get fungus growth on storage.

4.1 Clark and Lubs Buffer Solutions (25°C)

4.1.1 *p*H *1·2 to 2·2* — prepared by mixing hydrochloric acid (0·2 N) and potassium chloride solution (0·2 N) and diluting to one litre, with water.

Composition per litre of the solution:

		*p*H
425·0 ml hydrochloric acid	+ 250 ml potassium chloride solution	1·2
266·0 ,, ,,	+ 250 ,, ,,	1·4
162·0 ,, ,,	+ 250 ,, ,,	1·6
102·0 ,, ,,	+ 250 ,, ,,	1·8
65·0 ,, ,,	+ 250 ,, ,,	2·0
39·0 ,, ,,	+ 250 ,, ,,	2·2

4.1.2 *p*H *2·2 to 4·0* — prepared by mixing hydrochloric acid (0·2 N) and potassium hydrogen phthalate solution (0·2 M) and diluting to one litre with water.

Composition per litre of the solution:

		*p*H
247·5 ml hydrochloric acid	+ 250 ml potassium hydrogen phthalate solution	2·2
211·0 ,, ,,	+ 250 ,, ,,	2·4
177·0 ,, ,,	+ 250 ,, ,,	2·6
144·5 ,, ,,	+ 250 ,, ,,	2·8
111·5 ,, ,,	+ 250 ,, ,,	3·0
78·5 ,, ,,	+ 250 ,, ,,	3·2
52·0 ,, ,,	+ 250 ,, ,,	3·4
31·5 ,, ,,	+ 250 ,, ,,	3·6
14·5 ,, ,,	+ 250 ,, ,,	3·8
20·0 ,, ,	+ 250 ,, ,,	4·0

4.1.3 *p*H *4·2 to 5·8* — prepared by mixing sodium hydroxide solution (0·2 N) and potassium hydrogen phthalate solution (0·2 M) and diluting to one litre with water.

Composition per litre of the solution:

		*p*H
15·0 ml sodium hydroxide solution	+ 250 ml potassium hydrogen phthalate solution	4·2
33·0 ,, ,,	+ 250 ,, ,,	4·4
55·5 ,, ,,	+ 250 ,, ,,	4·6
82·5 ,, ,,	+ 250 ,, ,,	4·8
113·0 ,, ,,	+ 250 ,, ,,	5·0
144·0 ,, ,,	+ 250 ,, ,,	5·2
170·5 ,, ,,	+ 250 ,, ,,	5·4
194·0 ,, ,,	+ 250 ,, ,,	5·6
211·5 ,, ,,	+ 250 ,, ,,	5·8

4.1.4 *p*H *5·8 to 8·0* — prepared by mixing sodium hydroxide solution (0·2 N) and potassium dihydrogen phosphate (0·2 M) and diluting to one litre with water.

Composition per litre of the solution:

		*p*H
18·0 ml sodium hydroxide solution	+ 250 ml potassium dihydrogen phosphate solution	5·8
28·0 ,, ,,	+ 250 ,, ,,	6·0
40·5 ,, ,,	+ 250 ,, ,,	[illegible]
58·0 ,, ,,	+ 250 ,, ,,	6·4
82·0 ,, ,,	+ 250 ,, ,,	6·6
112·0 ,, ,,	+ 250 ,, ,,	6·8
145·5 ,, ,,	+ 250 ,, ,,	7·0
173·5 ,, ,,	+ 250 ,, ,,	7·2
195·5 ,, ,,	+ 250 ,, ,,	7·4
212·0 ,, ,,	+ 250 ,, ,,	7·6
222·5 ,, ,,	+ 250 ,, ,,	7·8
230·5 ,, ,,	+ 250 ,, ,,	8·0

4.1.5 *p*H *8·0 to 10·0* — prepared by mixing sodium hydroxide solution (0·2 N), and boric acid solution (0·2 M) in potassium chloride solution (0·2 M) and diluting the mixture to one litre with water. These solutions shall be checked to account for the influence of carbon dioxide.

Composition per litre of the solution:

				*p*H
19·5 ml sodium hydroxide solution	+	250 ml boric acid-potassium chloride solution		8·0
30·0 „ „	+	250 „ „		8·2
43·0 „ „	+	250 „ „		8·4
59·0 „ „	+	250 „ „		8·6
79·0 „ „	+	250 „ „		8·8
104·0 „ „	+	250 „ „		9·0
132·0 „ „	+	250 „ „		9·2
160·5 „ „	+	250 „ „		9·4
184·5 „ „	+	250 „ „		9·6
203·0 „ „	+	250 „ „		9·8
218·5 „ „	+	250 „ „		10·0

4.2 Sorensen Buffer Solutions (18°C)

4.2.1 *p*H *1·04 to 3·68* — prepared by mixing hydrochloric acid (0·1 N) and glycine solution (0·1 M) in sodium chloride solution (0·1 N).

Composition of the solution:

			*p*H
0·0 ml glycine-sodium chloride solution	+	100 ml hydrochloric acid	1·04
10·0 „ „	+	90 „ „	1·15
20·0 „ „	+	80 „ „	1·25
30·0 „ „	+	70 „ „	1·42
40·0 „ „	+	60 „ „	1·64
50·0 „ „	+	50 „ „	1·93
60·0 „ „	+	40 „ „	2·28
70·0 „ „	+	30 „ „	2·61
80·0 „ „	+	20 „ „	2·92
90·0 „ „	+	10 „ „	3·34
95·0 „ „	+	5 „ „	3·68

4.2.2 *p*H *8·24 to 10·14* — prepared by mixing sodium hydroxide solution (0·1 N), and glycine solution (0·1 M) in sodium chloride solution (0·1 N).

Composition of the solution:

			*p*H
97·5 ml glycine-sodium chloride solution	+	2·5 ml sodium hydroxide solution	8·24
95·0 „ „	+	5·0 „ „	8·58
90·0 „ „	+	10·0 „ „	8·93
80·0 „ „	+	20·0 „ „	9·36
70·0 „ „	+	30·0 „ „	9·71
60·0 „ „	+	40·0 „ „	10·14

4.3 Michaelis Buffer Solutions (25°C)

4.3.1 *Veronal-Sodium Hydroxide Buffer Solutions for Physiological Purposes* (*p*H *7·00 to 9·20*) — prepared with sodium salt of veronal solution (0·1 M) and hydrochloric acid (0·1 N).

Composition of the solution:

		*p*H
53·6 ml sodium salt of veronal solution	+ 46·4 ml hydrochloric acid	7·00
55·4 ,, ,,	+ 44·6 ,, ,,	7·20
58·1 ,, ,,	+ 41·9 ,, ,,	7·40
61·5 ,, ,,	+ 38·5 ,, ,,	7·60
66·2 ,, ,,	+ 33·8 ,, ,,	7·80
71·6 ,, ,,	+ 28·4 ,, ,,	8·00
76·9 ,, ,,	+ 23·1 ,, ,,	8·20
82·3 ,, ,,	+ 17·7 ,, ,,	8·40
87·1 ,, ,,	+ 12·9 ,, ,,	8·60
90·8 ,, ,,	+ 9·2 ,, ,,	8·80
93·6 ,, ,,	+ 6·4 ,, ,,	9·00
95·2 ,, ,,	+ 4·8 ,, ,,	9·20

4.3.2 *Veronal-Acetate Buffer Solutions* (*p*H *2·62 to 9·64*) — isotonic with blood at 25°C. The veronal-acetate solution shall contain 19·43 g of sodium acetate and 29·43 g of sodium salt of veronal in 1 litre of the solution made in carbon dioxide-free water.

4.3.2.1 To make 25 ml of the buffer solution, take 5 ml of the veronal-acetate solution (4.3.2) and mix 2 ml of sodium chloride solution (8·5 percent *w/v*) and the following amounts of hydrochloric acid (0·1 N) and dilute to 25 ml with carbon dioxide-free water:

Volume of Hydrochloric Acid (ml)	*p*H
0·0	9·64
0·25	9·16
0·50	8·90
0·75	8·68
1·0	8·55
2·0	8·18
3·0	7·90
4·0	7·66
5·0	7·42
5·5	7·25
6·0	6·99
6·5	6·75
7·0	6·12

Volume of Hydrochloric Acid (ml)	*p*H
8·0	5·32
9·0	4·93
10·0	4·66
11·0	4·33
12·0	4·13
13·0	3·88
14·0	3·62
15·0	3·20
16·0	2·62

4.4 Britton and Robinson Universal Buffer Solutions (*p*H 1·81 to 11·98) — prepared by adding the following volumes of sodium hydroxide solution (0·2 N) to 100 ml of a solution of mixed acid, being 0·04 M with respect to phosphoric acid, 0·04 N with respect to both acetic and boric acids:

Volume of Sodium Hydroxide Solution (ml)	*p*H
0·0	1·81
2·5	1·89
5·0	1·98
7·5	2·09
10·0	2·21
12·5	2·36
15·0	2·56
17·5	2·87
20·0	3·29
22·5	3·78
25·0	4·10
27·5	4·35
30·0	4·56
32·5	4·78
35·0	5·02
37·5	5·33
40·0	5·72
42·5	6·09
45·0	6·37
47·5	6·59
50·0	6·80
52·5	7·00
55·0	7·24
57·5	7·54
60·0	7·96
62·5	8·36
65·0	8·69

Volume of Sodium Hydroxide Solution (ml)	*p*H
67·5	8·95
70·0	9·15
72·5	9·37
75·0	9·62
77·5	9·91
80·0	10·38
82·5	10·88
85·0	11·20
87·5	11·40
90·0	11·58
92·5	11·70
95·0	11·82
97·5	11·92
100·0	11·98

4.5 Buffer Solutions of *p*H 9·6 to 13·0 (25°C)

4.5.1 *p*H *9·6 to 11·0* — prepared by mixing sodium bicarbonate solution (0·05 M) and sodium hydroxide solution (0·1 N) and diluting to one litre with water.

Composition per litre of the solution:

			*p*H
50·0 ml sodium hydroxide solution	+	500 ml bicarbonate solution	9·60
76·0 „ „	+	500 „ „	9·80
107·0 „ „	+	500 „ „	10·00
138·0 „ „	+	500 „ „	10·20
165·0 „ „	+	500 „ „	10·40
191·0 „ „	+	500 „ „	10·60
212·0 „ „	+	500 „ „	10·80
227·0 „ „	+	500 „ „	11·00

4.5.2 *p*H *10·9 to 12·0* — prepared by mixing disodium hydrogen phosphate solution (0·05 M) and sodium hydroxide solution (0·1 N) and diluting to one litre with water.

Composition per litre of the solution:

			*p*H
33·0 ml sodium hydroxide solution	+	500 ml disodium hydrogen phosphate solution	10·90
41·0 „ „	+	500 „ „	11·00
63·0 „ „	+	500 „ „	11·20
91·0 „ „	+	500 „ „	11·40
135·0 „ „	+	500 „ „	11·60
194·0 „ „	+	500 „ „	11·80
269·0 „ „	+	500 „ „	12·00

4.5.3 *p*H *12·0 to 13·0* — prepared by mixing potassium chloride solution (0·2 M) and sodium hydroxide solution (0·2 N) and diluting to one litre with water.

Composition per litre of the solution:

			*p*H
60·0 ml sodium hydroxide solution	+	250 ml potassium chloride solution	12·00
102·0 „ „	+	250 „ „	12·20
162·0 „ „	+	250 „ „	12·40
256·0 „ „	+	250 „ „	12·60
412·0 „ „	+	250 „ „	12·80
660·0 „ „	+	250 „ „	13·00

4.6 Gomori Buffer Solutions (25°C) *p*H 7 to 9 for Physiological Purposes — prepared by mixing 0·1 M *tris* (hydroxymethyl) aminomethane and 0·1 N hydrochloric acid and diluting to one-litre with water.

Composition per litre of the solution:

466 ml hydrochloric acid	+	500 ml *tris* (hydroxymethyl) aminomethane solution	7·00
447 „ „	+	500 „ „	7·20
420 „ „	+	500 „ „	7·40
385 „ „	+	500 „ „	7·60
345 „ „	+	500 „ „	7·80
292 „ „	+	500 „ „	8·00
229 „ „	+	500 „ „	8·20
172 „ „	+	500 „ „	8·40
124 „ „	+	500 „ „	8·60
85 „ „	+	500 „ „	8·80
57 „ „	+	500 „ „	9·00

4.7 Walpole Buffer Solutions (18°C) *p*H 3·42 to 5·89 — prepared by mixing 0·2 N acetic acid and 0·2 M sodium acetate solution and diluting to one litre with water.

Composition per litre of the solution:

			*p*H
950 ml acetic acid	+	50 ml sodium acetate solution	3·42
900 ,, ,,	+	100 ,, ,,	3·72
800 ,, ,,	+	200 ,, ,,	4·05
700 ,, ,,	+	300 ,, ,,	4·27
600 ,, ,,	+	400 ,, ,,	4·45
500 ,, ,,	+	500 ,, ,,	4·63
400 ,, ,,	+	600 ,, ,,	4·80
300 ,, ,,	+	700 ,, ,,	4·99
200 ,, ,,	+	800 ,, ,,	5·23
150 ,, ,,	+	850 ,, ,,	5·37
100 ,, ,,	+	900 ,, ,,	5·57
50 ,, ,,	+	950 ,, ,,	5·89

5. PRIMARY AND SECONDARY BUFFER SOLUTIONS

5.1 For checking the *p*H of solutions prepared in **4**, a *p*H meter shall be employed which shall be calibrated against primary and secondary buffer solutions given in Table 1. The solutions given are arranged in the table in the order of increasing *p*H values.

TABLE 1 STANDARD PRIMARY AND SECONDARY BUFFER SOLUTIONS AT 25°C

(*Clause* 5.1)

SL No.	BUFFER SOLUTION	MOLALITY (m)	WEIGHT (IN AIR) OF BUFFER SUBSTANCE (g/l) at 25°C	pH at 25°C	DILUTION VALUE ($\Delta p\mathrm{H}_{\frac{1}{2}}$)	BUFFER VALUE (β)	TEMPERATURE COEFFICIENT $\frac{dp\mathrm{H}}{dt}$
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
i)	Potassium tetra-oxalate	0·05	12·61	1·679	+ 0·186	0·070	+ 0·001
ii)	Potassium hydrogen tartrate	0·034 (approx)	Saturated at 25°C	3·557	+ 0·049	0·027	— 0·001 4
iii)	Potassium hydrogen phthalate	0·05	10·12	4·008	+ 0·052	0·016	+ 0·001 2
iv)	Potassium dihydrogen phosphate *PLUS* disodium hydrogen phosphate	0·025 0·025	3·39 3·53	6·865	+ 0·080	0·029	— 0·002 8
v)	Potassium dihydrogen phosphate *PLUS* disodium hydrogen phosphate	0·008 695 0·030 43	1·179 4·30	7·413	+ 0·07	0·016	— 0·002 8
vi)	Borax	0·01	3·80	9·180	+ 0·01	0·020	— 0·008 2
vii)	Calcium hydroxide	0·020 3	Saturated at 25°C	12·454	— 0·28	0·09	- 0·033

NOTE — Solutions (ii) to (vi) are primary standards, and (i) and (vii) are secondary standards.

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